

***Geothermal
Resource
Technologies, Inc.***

1444 Rogers Court • Allen, TX 75013-5451 • (972) 390-1537 • Fax: (972) 390-1851

FORMATION THERMAL CONDUCTIVITY TEST AND DATA ANALYSIS

Analysis for

**Metcalfe County
Attn: Judge Donald Butler
100 East Stockton St., Suite 3
Edmonton, Kentucky 42147
(207) 432-3181 • Fax: (370) 432-3726**

Test location

**Metcalfe County Courthouse
Edmonton, KY**

May 9, 2001

Test Performed by

Geothermal Resource Technologies, Inc.

36.98041
085.61044

Executive Summary

A formation thermal conductivity test was performed at the site of the Metcalfe County Courthouse in Edmonton, KY. The vertical bore was previously installed by Mid South Drilling. The test unit was attached to the vertical bore on the afternoon of Thursday, May 3, 2001. The collected data was analyzed by Geothermal Resource Technologies, Inc. under the supervision of Charles Remund, Ph.D., Director of Engineering.

This report provides a general overview of the test and procedures that were used to perform the thermal conductivity test along with a plot of the data in real time and in a form used to calculate the formation thermal conductivity. The following average formation thermal conductivity was found from the data analysis.

$$\Rightarrow \text{Formation Thermal Conductivity} = 1.32 \text{ Btu/hr-ft-}^{\circ}\text{F}$$

Due to the necessity of a thermal diffusivity value in the design calculation process, an attempt was made to estimate the average thermal diffusivity for the encountered formation.

$$\Rightarrow \text{Formation Thermal Diffusivity} \approx 0.89 \text{ ft}^2/\text{day}$$

A copy of the original collected data is available either in a hard copy or an electronic format upon request.

Test Procedure

The procedure for the formation thermal conductivity test is as follows:

1. Connect the u-bend ground heat exchanger pipe to the portable FTC unit.
2. Connect the data acquisition unit to the wiring harness in the FTC unit.
3. Connect the FTC unit to 240 volt power supply (collected data indicated the average voltage throughout the tests was 234.0 volts).
4. Fill and purge air from the FTC unit.
5. Insulate the exposed u-bend pipes (leading from the well bore surface to the FTC unit).
6. Simultaneously turn on the heating elements and initiate the data acquisition device.
7. Routinely monitor that the power supply remains connected and the water level of the fluid reservoir within the FTC unit stays at an acceptable level.
8. After the test is completed, turn off heating elements, the circulation pump, and the data acquisition device.

Data Analysis

Geothermal Resource Technologies, Inc. uses the "line source" method of data analysis. The line source equation used is not valid for early test times. Also, the line source method assumes an infinitely thin line source of heat in a continuous medium. If a u-bend grouted in a borehole is used to inject heat into the ground at a constant rate in order to determine the average formation thermal conductivity, the test must be run long enough to allow the finite dimensions of the u-bend pipes and the grout to become insignificant. Experience has shown that the amount of time required to allow early test time error and finite borehole dimension effects to become insignificant is approximately ten hours.

In order to analyze real data from a formation thermal conductivity test, the average temperature of the water entering and exiting the u-bend heat exchanger is plotted versus the natural log of time. Using the Method of Least Squares, the linear equation coefficients are then calculated that produce a line that fits the data. This procedure is normally repeated for various time intervals to ensure that variations in the power or other effects are not producing erroneous results.

Through the analysis process, the collected raw data is converted to spreadsheet format (Microsoft Excel®) for final analysis. A copy of this data can be obtained either in a hard copy or electronic copy format at any time. If desired, please contact Geothermal Resource Technologies, Inc. and provide a ship-to address or e-mail address at one of the following:

Phone: (972) 390-1537

Fax: (972) 390-1851

E-mail: askouby@grti.com

Formation Thermal Conductivity Test Report

Date May 3 - 5, 2001
Location Edmonton, KY

Borehole Data

Undisturbed Soil Temperature Appox. 59° F
Borehole Depth 300 ft.
Borehole Diameter 6"

Drill Log	Dirt/Broken Rock	0 - 12'
	Soft Light-Gray Limestone	10 - 184'
	Dark Brown Shale	184 - 185'
	Med.-Gray Limestone	185 - 225'
	Med.-Gray Hard Limestone	225 - 300'

U-bend Size 1 in. HDPE
U-Bend Length 300 ft.
Grout Type Cuttings
Grouted Portion 300 ft
Grout Solids NA

Test Data

Test Duration 39.2 hrs.
Average Power 4,416 W
Calculated Circulator Flow Rate 6.4 gpm
Total Heat Input Rate 15,072 Btu/hr

Metcalfe County Courthouse, Edmonton, KY

May 3 - 5, 2001

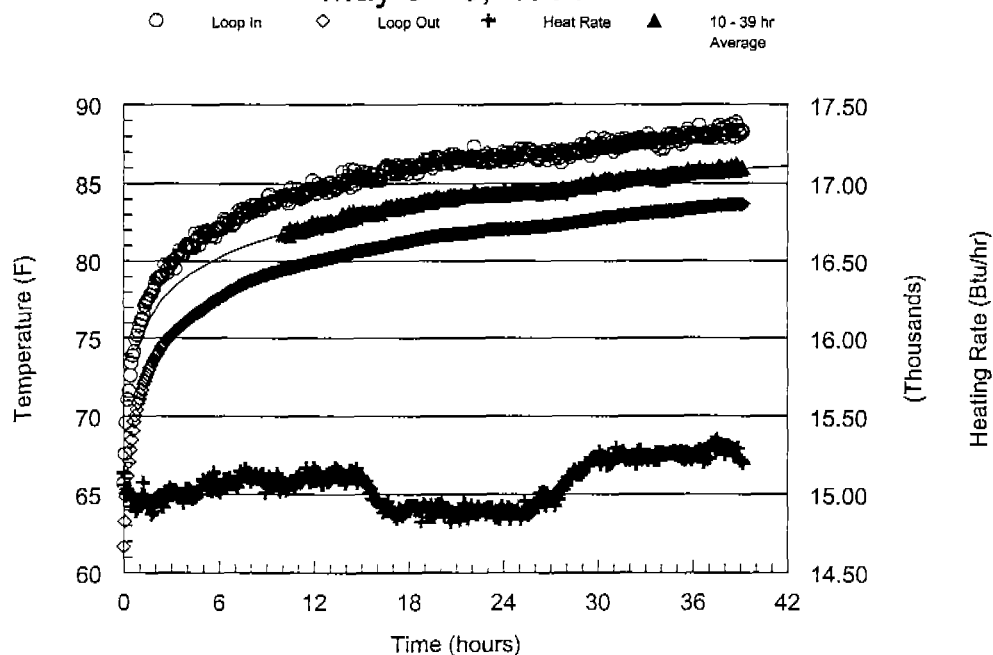


Figure 1: Temperature versus Time Data

May 9, 2001

GRTI
FTC Test and Data Analysis
Page 5 of 7

Line Source Data Analysis

Metcalfe County Courthouse, Edmonton, KY

May 3 - 5, 2001

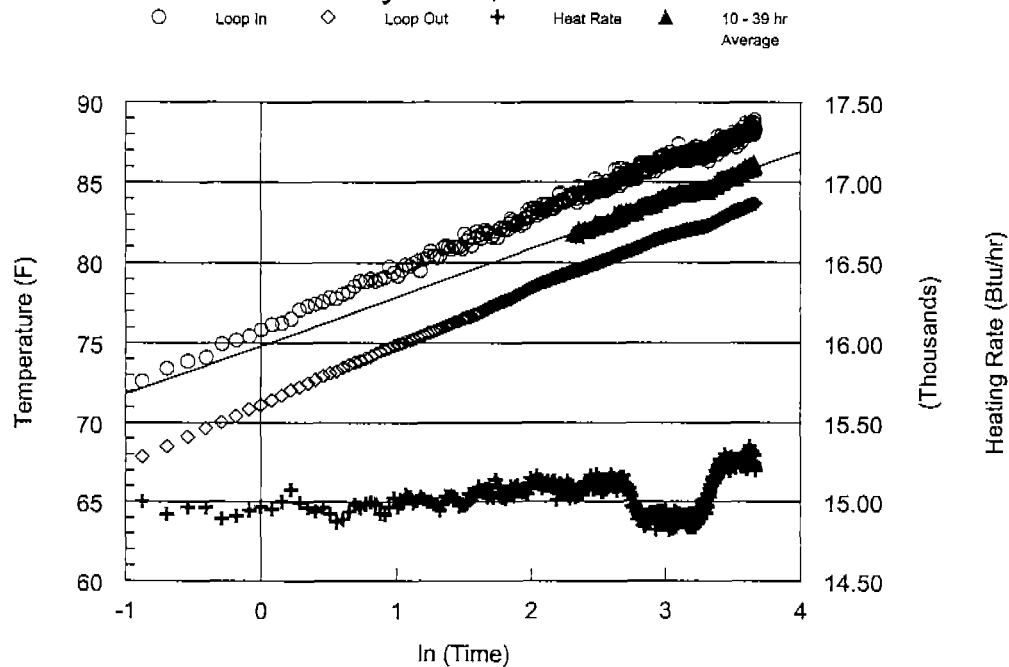


Figure 2: Temperature versus Natural Log of Time

Time Period	Slope: a_1	Average Heat Input (Btu/hr-ft)	Thermal Conductivity (Btu/hr-ft-°F)
10 – 39.2 hrs	3.02	50.24	1.32

The temperature versus time data was analyzed using the line source analysis for the time period shown above. An average linear curve fit was applied to the data between 10 and 39.2 hours. The slope of the curve (a_1) was found to be 3.02. The resulting thermal conductivity was found to be 1.32 Btu/hr-ft-°F.

Estimated Thermal Diffusivity

The reported drilling log for this test borehole indicated that the formation consisted mainly of limestone. A heat capacity value for limestone was calculated from specific heat and density values listed by Kavanaugh and Rafferty (Ground-Source Heat Pumps - Design of Geothermal Systems for Commercial and Institutional Buildings, ASHRAE, 1997). A weighted average of these values based on the indicated formation was used to develop an average heat capacity for the formation. An estimated diffusivity value was then found using the calculated formation thermal conductivity and the estimated average heat capacity. The thermal diffusivity for this formation was estimated to be approximately 0.89 ft²/day.

Est. Average Heat Capacity (Btu/ft ³ °F)	Thermal Conductivity (Btu/hr-ft-°F)	Est. Thermal Diffusivity (ft ² /day)
39.2	1.32	0.89

MID-SOUTH DRILLING, INC.

P. O. Box 297

Lebanon, TN 37088-0297

(615) 444-0423 • Fax (615) 444-0427

WORK ORDER

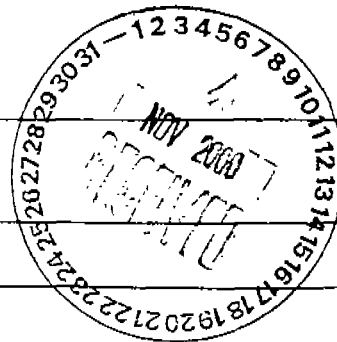
00336

Date 9-27-00

METCALF COUNTY

~~LEBANON~~ JUSTICE CENTER

Job Description



1ST HOLE - HOOP INSTALLED

0-12 ft. DIRT & BROKEN ROCK

~~12-100 ft.~~ VERY SOFT LIGHT GRAY Limestone

100-184 ft. SOFT GRAY Limestone

184/185 ft. DARK BROWN SHALE

185-225 ft. MEDIUM GRAY Limestone

225-300 ft. MEDIUM HARD GRAY Limestone

2ND HOLE - NO HOOP

0-10 ft. DIRT & BROKEN ROCK

10-100 ft. VERY SOFT LIGHT GRAY Limestone

100-180 ft. SOFT GRAY Limestone

180/181 ft. DARK BROWN SHALE

181-200 ft. MEDIUM GRAY Limestone

200-300 ft. MEDIUM HARD GRAY Limestone

NEITHER HOLE HAD MEASURABLE AMOUNT OF WATER

36.98041

085.61044

Received by _____

Date _____